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CONTRACT REPORT ARBRL-CR-0476

MODIFICATIONS OF OIL-TYPE COMPUTER PROGRAMS

Prepared by

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

During the course of this contract, modifications for solving specific shaped-charge penetration problems were made to OIL-type computer codes that are operational at the Ballistic Research Laboratory. Set-up instructions were provided for the Ballistic Research Laboratory's versions of 2DCLAM, 3DCLAM, 2DSOIL, and 3DSOIL. The latter two codes are advanced operator splitting versions of DORF and TRIDORF. A series of tests were conducted to check-out the SOIL codes.

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I. INTRODUCTION

Target configurations for studying penetration by shaped-charge jets are becoming more complex; consequently, numerical techniques, capable of performing computations with more than two materials in a computational cell (such as the case with the DORF[1] and TRIDORF[2] codes), are required. The advanced operator splitting versions of DORF and TRIDORF, referred to as the 2DSOIL and 3DSOIL codes, respectively, have the capability of treating up to four materials within a computational cell.

An accurate treatment of free-surface movement is necessary for thin targets and multiple material targets. Special free-surface treatments have been incorporated into the 2DSOIL aud TRIDORF codes.

For computational problems involving large stresses, the available viscosity due to material advection is adequate to accurately describe the stress, density, and velocity fields. However, at lower stresses, an artificial viscosity prescription is required to dampen the oscillatory flow results. An artificial viscosity routine which is incorporated into the solution during compression and rarefaction phases is now available in the 2DSOIL and 3DSOIL codes.

The early versions of TRIDORF and 3DSOIL contained very primitive and limited methods for generating starting data for the codes. Generator codes (similar to the CLAM[2] code) have been developed and checked out for the 3DSOIL and TRIDORF codes.

Test problems (Section VI, Summary and Conclusions) have been completed for the purpose of comparing two-dimensional results from a two-dimensional code to the two-dimensional results from a three-dimensional code.

Sections II thru V contain operating instructions for the Ballistic Research Laboratory's versions of the 2DCLAM, 2DSOIL, 3DCLAM, and 3DSOIL codes.

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[1] *Johnson, W. E., "Development and Applications of Computer Programs to Hypervelocity Impact," Systems, Science and Software Report 3SR-749, July 1971.*

[2] *Johnson, W. E., "TRIDORF - A Two-Material Version of the TRIOIL Code with Strength," Computer Code Consultants Report CCC-976, September 1976.*

II. 2DCLAM INPUT

Units are in jerks, grams, kev, centimeters, and shakes where 1 jerk = 10^{16} ergs and 1 shake = 10^{-8} s.

An asterisk signifies that the datum is entered in a real number format; otherwise, it is entered in an integer format.

CARD NUMBER	COLUMN	DESCRIPTION
1	2 - 72	Header card for comments
2	* 1 - 10	Problem number
	* 11 - 20	Maximum number of cells in the r-direction (IMAX)
	* 21 - 30	Maximum number of cells in the z-direction (JMAX)
	* 31 - 40	0. for hydrodynamic and radiation computations or 1. for hydrodynamic and strength computations
	* 41 - 50	0. for no tracer particles or 2. for tracer particles
	* 51 - 60	0. for r-z geometry or 1. for x-y plane-strain geometry
	* 61 - 70	Calls the REZONE routine and is equal to the tape number from ADJUST; otherwise, set to 0.
	71 - 72	Binary tape number
3 (Cell Dimensions) Several Number type cards are required.	1	1 if this is the last DX or DY card or 0 if there are more DX or DY cards
	2	0 for DX data or 1 for DY data
	3 - 4	Number of cells that will have the DX or DY value in columns 11 - 20
	5 - 6	Number of cells that will have the DX or DY value in columns 21 - 30

CARD NUMBER	COLUMN	DESCRIPTION
	7 - 8	Number of cells that will have the DX or DY value in columns 31 - 40
	9 - 10	Number of cells that will have the DX or DY value in columns 41 - 50
	* 11 - 20	Value of DX or DY
	* 21 - 30	Value of DX or DY
	* 31 - 40	Value of DX or DY
	* 41 - 50	Value of DX or DY

If DX or DY above is negative, DX(I) = DX(I - 1)*ABS(value) or DY(I) = DY(I - 1)*ABS(value).

Last card of set	* 21 - 30	80.

Insert data cards for CUBIT if S9 > 0.

Geometry and ρ, I, U, and V Input

CARD NUMBER	COLUMN	DESCRIPTION
1	1	Load a 1
	5 - 7	N^2, the number of particles per cell ($1 \leq N \leq 20$)
	* 11 - 20	Z-coordinate for the origin of the radius vector for the FIT routines (YC)
	* 21 - 30	R-coordinate for the origin of the radius vector for the FIT routines (XC)
	* 31 - 40	FIT number (1 thru 6) to use to compute I, U, V, and ρ
	* 41 - 50	Material number (1 thru 4)
	* 51 - 60	Specific heat

Following the first card of each package are five possible data cards:

1. Generate geometry
2. Non-generate geometry
3. Density
4. Specific internal energy
5. Velocity (U and V)

Note: Many Number 1 and Number 2 cards may be used (maximum of 72), but only one each of cards 3, 4, and 5 may be used.

GEOMETRY	COLUMN	DESCRIPTION
1. Rectangle	1	Load a 4
	7	Load a 1 to generate Load a 0 to void
	* 11 - 20	Left X of rectangle
	* 21 - 30	Right X of rectangle
	* 31 - 40	Lower Y of rectangle
	* 41 - 50	Upper Y of rectangle
2. Triangle	1	Load a 6
	7	Load a 1 to generate Load a 0 to void
	* 11 - 20	X1-coordinate of vertex 1
	* 21 - 30	Y1-coordinate of vertex 1
	* 31 - 40	X2-coordinate of vertex 2
	* 41 - 50	Y2-coordinate of vertex 2
	* 51 - 60	X3-coordinate of vertex 3
	* 61 - 70	Y3-coordinate of vertex 3
3. Ellipse or Circle	1	Load a 4
	2	Load a 1
	7	Load a 1 to generate Load a 0 to void

GEOMETRY	COLUMN	DESCRIPTION
	* 11 - 20	Semi-axis in R of an ellipse; radius of a circle
	* 21 - 30	Semi-axis in Z of an ellipse; 0. for a circle
	* 31 - 40	R coordinate of the center of the ellipse or circle
	* 41 - 50	Z coordinate of the center of the ellipse or circle

Following the geometry cards are data cards that refer to all cells within the package:

1. Density card (load a 51 in columns 1-2)
2. Specific internal energy card (load a-52 in columns 1-2)
3. Velocity (U and V) card (load a 53 in columns 1-2)

The data for ρ (TABR array), I (TABI array), U (TABUV array), and V (TABUV array) are loaded in real number format in columns 11 - 20, 21 - 30, 31 - 40, 41 - 50, 51 - 60, and 61 - 70.

FIT routines are provided for analytical or table fits for each package. FIT3, FIT4, FIT5, and FIT6 are blank and are available to the user. FIT1 and FIT2 are described below. FIT numbers are specified on the first card of each package.

The FIT routine will assign a density, specific internal energy, and velocity components to each particle, N, having coordinate TTX (the r-coordinate of particle N relative to the origin of the radius vector) and coordinate TTY (the z-coordinate of particle N relative to the origin of the radius vector).

The standard output from the FIT routines is

WSR, the particle density of particle N
WSI, the specific internal energy of particle N
WSU, the r-velocity component of particle N
WSV, the z-velocity component of particle N

FIT1

FORTRAN Expression	Analytic Expression
WSR = TABR(1)	ρ = constant
WSI = TABI(1)	I = constant
WSU = TABUV(1)	U = constant
WSV = TABUV(2)	V = constant

FIT2

FORTRAN Expression	Analytic Expression
WS = SQRT(TTX**2 + TTY**2)	$R = (r^2 + z^2)^{\frac{1}{2}}$
WSR = TABR(1) + TABR(2)*WS	$\rho = a + bR$
WSI = TABI(1) + TABI(2)*WS	$I = c + dR$
WSS = TABUV(1) + TABUV(2)*WS	$S = e + fR$
WSU = WSS*TTX/WS	$U = Sr/R$
WSV = WSS*TTY/WS	$V = Sz/R$
	where a, b, c, d, e, and f are constants.

The last card of the geometry set will have a 2 in column 1.

Additional data cards will be called if N10 > 1.

Tracer Particle Option

COLUMN 1	COLUMNS 4 - 6	VARIABLE	DESCRIPTION
2	56	L1	The number of particle packages to be generated
1	100	I4	Load a 1.0

There will be L1 of the following sets:

2	67	N1	Number of tracer particles for this set (for a circle, the code gives 2*N1 particles

1. Circle Option

1	29	S1	0. for a circle of particles
1	30	S2	R-coordinate of the center of the circle
1	31	S3	Z-coordinate of the center of the circle
1	32	S4	Radius of the circle

2. Line Segment Option

1	29	S1	1. for a line segment of particles
1	30	S2	X1-coordinate of an end point of the line

COLUMN 1	COLUMNS 4 - 6	VARIABLE	DESCRIPTION
1	31	S3	Y1-coordinate of an end point of the line segment
1	32	S4	X2-coordinate of an end point of the line segment
1	33	S5	Y2-coordinate of an end point of the line segment

Each of the L1 sets will end with a card:

COLUMN 1	COLUMNS 4 - 6	COLUMNS 8 - 9
1	100	1.

III. 2DSOIL INPUT

Units are in jerks, grams, kev, centimeters, and shakes where

1 jerk = 10^{16} ergs and 1 shake = 10^{-8} s.

All data loaded via the CARD routine are in a real number format. A 2 in column 1 instructs the CARD routine (data loader) to convert input real numbers to an integer format.

There are three sets of data cards. A 1 in column 1 designates a card to be the last in the second and third sets of data cards.

First Set

Card 1: Column 3 contains N, the number of header cards that are used for comments.

Next N cards: Comments in columns 2 thru 72.

Second Set

Column 1	Columns 4-6	Variable	Description
2	73	N7	Number of binary tape to be read
2	85	NMAX	0. for no tracer particles or 1. for tracer particles
2	96	NST	0. for hydrodynamic computations or 1. for hydrodynamic and strength computations
	151	PK(1)	Problem number
1	152	PK(2)	Cycle number for restart

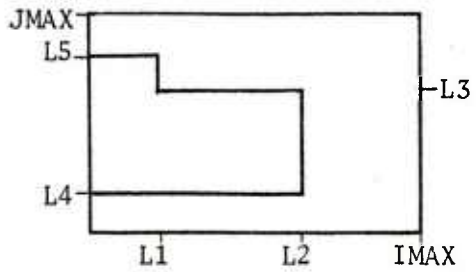
Third Set

Column 1	Columns 4-6	Variable	Description
	6	PMIN	Minimum pressure
	9	UMIN	Minimum velocity
	10	EIMIN	Minimum specific internal energy

Column 1	Columns 4-6	Variable	Description
	11	RADC	0. for no radiation computations or .0137 jerks/cc/kev for radiation diffusion computations
	16	THEMIN	Minimum temperature (kev)
	17	CLITE	300 cm/shake, radiation velocity
	18	ALPHA	1., implicit coefficient for radiation flow
	21	DTOPTN	-1., the code will control the time step using the Courant and particle velocity conditions or 1., the code will use the loaded constant time step
	23	ESTAB	Early time stability
	24	EPSLN	Minimum flux (ρ) at free surface when E > EMELT
	25	FSTAB	Final time stability
	26	RHOMIN	Minimum density for cell to be checked for time change stability
	27	BGTHE	Background temperature (kev)
	28	TCUT	Use units of θ^4 If θ > TCUT, the stability (radiation) is checked if the zone is either cooling or heating, or, if θ <TCUT, the stability (radiation) is checked only if the zone is cooling
	29	S1	.5, factor in MFLUX routine
	37	S9	.01, epsilonics in strength
	38	S10	Projectile velocity at t = 0.
	43	FEF	allowable energy change, $\Delta E/E$, per cycle for radiation flow
	44	FACT	Factor for increasing ESTAB per cycle until ESTAB = FSTAB

Column 1	Columns 4-6	Variable	Description
	46	DMIN	Problem will stop on energy check if $\lvert \Delta E/E/\text{cycle} \rvert$ < DMIN
	47	Z(47)	Constant used in flux limiter at free surface in the radiation flow
	49	Z(49)	Minimum DX or DY

Note: L1 and L2 are right boundary values of a cell. L3 and L5 are top boundary values of a cell. L4 is the bottom boundary value of a cell.



2	54	L1	Active grid counter that is advanced or decreased after a computational cycle
2	55	L2	Active grid counter that is advanced or decreased after a computational cycle
2	56	L3	Active grid counter that is advanced or decreased after a computational cycle
2	57	L4	Active grid counter that is advanced or decreased after a computational cycle
2	58	L5	Active grid counter that is advanced or decreased after a computational cycle

Note: 1. indicates a reflective boundary condition;
-1. indicates a transmittive boundary condition.

2	59	LHL	Left hydrodynamic boundary condition
2	60	LHT	Top hydrodynamic boundary condition

Column 1	Columns 4-6	Variable	Description
2	61	LHR	Right hydrodynamic boundary condition
2	62	LHB	Bottom hydrodynamic boundary condition
2	63	LRL	Left radiation boundary condition
2	64	LRT	Top radiation boundary condition
2	65	LRR	Right radiation boundary condition
2	66	LRB	Bottom radiation boundary condition
2	67	NI	Maximum number of iterations in a mixed cell to achieve pressure equilibrium
2	75	N9	0. for no strength computations or 1. for strength computations
2	86	IFRAD	Maximum number of iterations (Newton-Raphson) for calculating the temperature from the energy equation
2	96	NST	0. for no strength computations or 1. for strength computations
	110	Z(110)	1.1*THETA (background for radiation-hydrodynamic computations) or 1.1*UMIN (for hydrodynamic-strength computations)
	146	TLP	Time frequency for long print
	147	DELP	Time interval for long print
	148	TDUMP	Time frequency for tape dump
	149	DELTD	Time interval for tape dump
	150	TSTOP	Time for problem to terminate normally
2	161	IDEQST(1)	Equation of state number for material 1
2	162	IDEQST(2)	Equation of state number for material 2
2	163	IDEQST(3)	Equation of state number for material 3

Column 1	Columns 4-6	Variable	Description
2	164	IDEQST(4)	Equation of state number material 4
2	170	IDEQST(10)	Total number of materials used in this problem
2	171	IDKAP(1)	Opacity routine for material 1
2	172	IDKAP(2)	Opacity routine for material 2
2	173	IDKAP(3)	Opacity routine for material 3
2	174	IDKAP(4)	Opacity routine for material 4
2	180	IDKAP(10)	0. for no artificial viscosity computations or 1. for artificial viscosity computations
	181	OPCON(1)	Linear viscosity coefficient
	182	OPCON(2)	Quadratic viscosity coefficient
	183	OPCON(3)	Maximum change in velocity. If the change is greater than OPCON(3), the artificial viscosity coefficient is set to 0.

Equation of State Data

M = 25(N - 1) where N is the material number (1 thru 4).

EQSTC(M+1) thru EQSTC(M+10) are constants for Tillotson's equation of state. EQSTC(M+11) thru EQSTC(M+25) are constants that are required for any form of an equation of state.

Column 1	Columns 4-6	Variable	Description
	431+M	EQSTC(M+1)	ρ_0 (g/cc)
	432+M	EQSTC(M+2)	a
	433+M	EQSTC(M+3)	I_0 (jerk/g)
	434+M	EQSTC(M+4)	b (jerk)
	435+M	EQSTC(M+5)	A (jerk/cc), bulk modulus

Column 1	Columns 4-6	Variable	Description
	436+M	EQSTC(M+6)	I_s (jerk/g)
	437+M	EQSTC(M+7)	I'_s (jerk/g)
	438+M	EQSTC(M+8)	α
	439+M	EQSTC(M+9)	β
	440+M	EQSTC(M+10)	B (jerk/g)
	441+M	EQSTC(M+11)	Not used
	442+M	EQSTC(M+12)	Not used
	443+M	EQSTC(M+13)	Not used
	444+M	EQSTC(M+14)	Not used
	445+M	EQSTC(M+15)	$10^{-5}*\rho_0$
	446*M	EQSTC(M+16)	$10^{-6}*\rho_0$
	447+M	EQSTC(M+17)	IMELT (jerk/g)
	448+M	EQSTC(M+18)	Y_0 (jerk/g), yield strength in shear
	449+M	EQSTC(M+19)	α in $Y = (Y_0 + \alpha P)$
	450+M	EQSTC(M+20)	μ, shear modulus
	451+M	EQSTC(M+21)	ρ/ρ_0 failure criterion
	452+M	EQSTC(M+22)	Maximum pressure in Y function above
	453+M	EQSTC(M+23)	Not used
	454+M	EQSTC(M+24)	Not used
	455+M	EQSTC(M+25)	Specific heat (jerk/g/kev)

IV. 3DCLAM INPUT

Units are in jerks, grams, kev, centimeters, and shakes where 1 jerk = 10^{16} ergs and 1 shake = 10^{-8} s.

An asterisk signifies that the datum is entered in a real number format; otherwise, it is entered in an integer format.

CARD NUMBER		COLUMN	DESCRIPTION
1		2 - 72	Header card for comments
2	*	1 - 10	Problem number
	*	11 - 20	Maximum number of cells in the x-direction (IMAX)
	*	21 - 30	Maximum number of cells in the y-direction (JMAX)
	*	31 - 40	Maximum number of cells in the z-direction (KMAX)
	*	51 - 60	0. for hydrodynamic computations or 1. for hydrodynamic and radiation computations or -1. for hydrodynamic and strength computations
		71 - 72	Binary tape number
3 (Cell Dimensions) At least 3 Number 3 type cards are required.		1	1 if this is the last DX, DY, or DZ data card or 0 if there are additional DX, DY, or DZ data cards
		2	0 for DX data or 1 for DY data or 2 for DZ data
		3 - 4	Number of cells that will have the DX, DY, or DZ value in columns 11-20
		5 - 6	Number of cells that will have the DX, DY, or DZ value in columns 21-30
		7 - 8	Number of cells that will have the DX, DY, or DZ value in columns 31-40

CARD NUMBER	COLUMN	DESCRIPTION
	9 - 10	Number of cells that will have the DX, DY, or DZ value in columns 41-50
	* 11 - 20	Value of DX, DY, or DZ
	* 21 - 30	Value of DX, DY, or DZ
	* 31 - 40	Value of DX, DY, or DZ
	* 41 - 50	Value of DX, DY, or DZ

If DX, DY, or DZ above are negative, DX(I) = DX(I - 1)*ABS(value), DY(I) = DY(I - 1)*ABS(value), or DZ(I) = DZ(I - 1)*ABS(value), respectively.

Last card of set	* 21 - 30	80.

Geometry and ρ, I, U, V, and W Input

Data is loaded to generate the following packages:

1. Parallelepiped
2. Tetrahedron which is triangular in the x-y plane and constant for all z planes
3. Sphere
4. Right circular cylinder with its axis parallel to the y-axis

CARD NUMBER	COLUMN	DESCRIPTION
1	1	Load a 1
	5 - 7	N^3, the number of particles per cell ($1 \leq N \leq 10$)
	* 11 - 20	X-coordinate for the origin of the radius vector for the FIT routines (XC)
	* 21 - 30	Y-coordinate for the origin of the radius vector for the FIT routines (YC)
	* 31 - 40	Z-coordinate for the origin of the radius vector for the FIT routines (ZC)

CARD NUMBER	COLUMN	DESCRIPTION
	* 41 - 50	FIT number (1 thru 6) used to compute ρ, I, U, V, and W for the N particles
	* 51 - 60	Material number (1 thru 4)
	* 61 - 70	Specific heat for material number 1, 2, 3, or 4

Following the first card of each package are five other types of data cards:

1. Generate geometry with options below
2. Delete geometry with options below
3. Density (only one per package)
4. Specific internal energy (only one per package)
5. Velocities U, V, or W (only one per package)

The density, specific internal energy and velocity components are generated per particle in the FIT routines.

For data cards 1 and 2 above, 3DCLAM has the options for generating or deleting the following geometries:

GEOMETRY	COLUMN	DESCRIPTION
1. Parallelepiped	1	Load a 4
	7	Load a 1 to generate or load a 0 to delete or omit generating
	* 11 - 20	Left x-coordinate of parallelepiped (X1)
	* 21 - 30	Right x-coordinate of parallelepiped (X2)
	* 31 - 40	Bottom y-coordinate of parallelepiped (Y1)
	* 41 - 50	Top y-coordinate of parallelepiped (Y2)
	* 51 - 60	Back z-coordinate of parallelepiped (Z1)
	* 61 - 70	Front z-coordinate of parallelepiped (Z2)

GEOMETRY	COLUMN	DESCRIPTION
2. Tetrahedron	1	Load a 6
	7	Load a 1 to generate or load a 0 to delete or omit generating
	* 11 - 20	X-coordinate of vertex 1
	* 21 - 30	Y-coordinate of vertex 1
	* 31 - 40	X-coordinate of vertex 2
	* 41 - 50	Y-coordinate of vertex 2
	* 51 - 60	X-coordinate of vertex 3
	* 61 - 70	Y-coordinate of vertex 3
3. Sphere	1	Load a 4
	2	Load a 1
	7	Load a 1 to generate or load a 0 to delete or omit generating
	* 11 - 20	Radius of sphere
	* 21 - 30	0.
	* 31 - 40	X-coordinate of the center of the sphere
	* 41 - 50	Y-coordinate of the center of the sphere
	* 51 - 60	Z-coordinate of the center of the sphere
4. Right circular cylinder with axis parallel to the y-axis	1	Load a 6
	2	Load a 1
	7	Load a 1 to generate or load a 0 to delete or omit generating
	* 11 - 20	Radius of cylinder

GEOMETRY	COLUMN	DESCRIPTION
	* 21 - 30	X-coordinate of the center of the cylinder
	* 31 - 40	Z-coordinate of the center of the cylinder
	* 41 - 50	Y-coordinate of the bottom of the cylinder
	* 51 - 60	Y-coordinate of the top of the cylinder

Following the geometry cards are the following data cards that refer to all the particles within this package:

1. Density card (load a 51 in columns 1-2)
2. Specific internal energy card (load a 52 in columns 1-2)
3. Velocity card (load a 53 in columns 1-2)

If the density, specific internal energy, and velocities for this package are the same as the previous package, a 51, 52, or 53 card is not required.

The data for ρ (TABR array), I (TABI array), U (TABUV array), V (TABUV array), and W (TABUV array) are loaded in real number format in columns 11 - 20, 21 - 30, 31 - 40, 41 - 50, 51 - 60, and 61 - 70.

FIT routines are provided for analytical or table fits for each package. FIT3, FIT4, FIT5, and FIT6 are blank and are available to the user. FIT1 and FIT2 are described below. FIT numbers are specified on the first card of each package.

The FIT routine will assign a density, specific internal energy, and velocity components to each particle, N, having coordinate TX (the x-coordinate of particle N), coordinate TY (the y-coordinate of particle N), and coordinate TZ (the z-coordinate of particle N). If point (TX,TY,TZ) is other than point (0,0,0), the coordinates of particle N are relocated to point (TTX,TTY,TTZ) by

$$TTX = TX - XC$$
$$TTY = TY - YC$$
$$TTZ = TZ - ZC$$

where point (XC,YC,ZC) is the origin of the position vector.

The standard output from the FIT routines is

WSR, the particle density of particle N
WSI, the specific internal energy of particle N
WSU, the x-velocity component of particle N
WSV, the y-velocity component of particle N
WSW, the z-velocity component of particle N

FIT1

FORTRAN Expression	Analytic Expression
WSR = TABR(1)	ρ = constant
WSI = TABI(1)	I = constant
WSU = TABUV(1)	U = constant
WSV = TABUV(2)	V = constant
WSW = TABUV(3)	W = constant

FIT2

FORTRAN Expression	Analytic Expression
WS = SQRT(TTX**2 + TTY**2 + TTZ**2)	$R = (x^2 + y^2 + z^2)^{\frac{1}{2}}$
WSR = TABR(1) + TABR(2)*WS	$\rho = a + bR$
WSI = TABI(1) + TABI(2)*WS	$I = c + dR$
WSS = TABUV(1) + TABUV(2)*WS	$S = e + fR$
WSU = WSS*TTX/WS	$U = Sx/R$
WSV = WSS*TTY/WS	$V = Sy/R$
WSW = WSS*TTZ/WS	$W = Sz/R$
	where a, b, c, d, e, and f are constants.

The last card of the geometry set will have a 2 in column 1.

V. 3DSOIL INPUT

Units are in jerks, grams, kev, centimeters, and shakes where 1 jerk = 10^{16} ergs and 1 shake = 10^{-8} s.

All data loaded via the CARD routine are in a real number format. A 2 in column 1 instructs the CARD routine (data loader) to convert input real numbers to an integer format.

There are three sets of data cards. A 1 in column 1 designates a card to be the last in the second and third sets of data cards.

First Set

Card 1: Column 3 contains N, the number of header cards that are used for comments.

Next N cards: Comments in columns 2 thru 72.

Second Set

Column 1	Columns 4-6	Variable	Description
2	73	N7	Number of binary tape to be read
2	85	NMAX	0. for no tracer particles or 1. for tracer particles
2	96	NST	0. for hydrodynamic computations or 1. for hydrodynamic and strength computations
	151	PK(1)	Problem number
1	152	PK(2)	Cycle number for restart

Third Set

Column 1	Columns 4-6	Variable	Description
	6	PMIN	Minimum pressure
	9	UMIN	Minimum velocity
	10	EIMIN	Minimum specific internal energy

Column 1	Columns 4-6	Variable	Description
	11	RADC	0. for no radiation computations or .0137 jerks/cc/kev for radiation diffusion computations
	12	Z(12)	Constant used in flux limiter at free surface in the radiation flow
	16	THEMIN	Minimum temperature (kev)
	17	CLITE	300 cm/shake, radiation velocity
	18	ALPHA	1., implicit coefficient for radiation flow
	21	DTOPTN	-1., the code will control the time step using the Courant and particle velocity conditions or 1., the code will use the loaded constant time step
	23	ESTAB	Early time stability
	24	EPSLN	Minimum flux (ρ) at free surface when E > EMELT
	25	FSTAB	Final time stability
	26	RHOMIN	Minimum density for cell to be checked for time change stability
	27	BGTHE	Background temperature (kev)
	28	TCUT	Use units of θ^4 If θ > TCUT, the stability (radiation) is checked if the zone is either cooling or heating, or, if θ < TCUT, the stability (radiation) is checked only if the zone is cooling
	37	S9	.01, epsilonics in strength
	38	S10	Y-component of projectile velocity at t = 0.
	43	FEF	allowable energy change, $\Delta E/E$, per cycle for radiation flow
	44	FACT	Factor for increasing ESTAB per cycle until ESTAB = FSTAB

Column 1	Columns 4-6	Variable	Description
	46	DMIN	Problem will stop on energy check if |E/E/cycle| < DMIN
	49	Z(49)	Minimum DX, DY, or DZ

Note: 1. indicates a reflective boundary condition;
-1. indicates a transmittive boundary condition.

2	59	LHL	Left hydrodynamic boundary condition
2	60	LHT	Top hydrodynamic boundary condition
2	61	LHR	Right hydrodynamic boundary condition
2	62	LHB	Bottom hydrodynamic boundary condition
2	63	LRL	Left radiation boundary condition
2	64	LRT	Top radiation boundary condition
2	65	LRR	Right radiation boundary condition
2	66	LRB	Bottom radiation boundary condition
2	67	NI	Maximum number of iterations in a mixed cell to achieve pressure equilibrium
2	75	N9	0. for no strength computations or 1. for strength computations
2	86	IFRAD	Maximum number of iterations (Newton-Raphson) for calculating the temperature from the energy equation
2	96	NST	0. for no strength computations or 1. for strength computations
	110	Z(110)	1.1*THETA (background for radiation-hydrodynamic computations) or 1.1*UMIN (for hydrodynamic-strength computations)
2	116	LLBB	Back hydrodynamic boundary conditions
2	117	LHF	Front hydrodynamic boundary conditions
2	118	LRBK	Back radiation boundary conditions

Column 1	Columns 4-6	Variable	Description
2	119	LRF	Front radiation boundary conditions
2	123	I1	Minimum active grid in the X-direction
2	124	I2	Maximum active grid in the X-direction
2	125	J1	Minimum active grid in the Y-direction
2	126	J2	Maximum active grid in the Y-direction
2	127	K1	Minimum active grid in the Z-direction
2	128	K2	Maximum active grid in the Z-direction
	146	TLP	Time frequency for long print
	147	DELP	Time interval for long print
	148	TDUMP	Time frequency for tape dump
	149	DELTD	Time interval for tape dump
	150	TSTOP	Time for problem to terminate normally
2	161	IDEQST(1)	Equation of state number for material 1
2	162	IDEQST(2)	Equation of state number for material 2
2	163	IDEQST(3)	Equation of state number for material 3
2	164	IDEQST(4)	Equation of state number material 4
2	170	IDEQST(10)	Total number of materials used in this problem
2	171	IDKAP(1)	Opacity routine for material 1
2	172	IDKAP(2)	Opacity routine for material 2
2	173	IDKAP(3)	Opacity routine for material 3
2	174	IDKAP(4)	Opacity routine for material 4

Column 1	Columns 4-6	Variable	Description
2	180	IDKAP(10)	0. for no artificial viscosity computations or 1. for artificial viscosity computations
	181	OPCON(1)	Linear viscosity coefficient
	182	OPCON(2)	Quadratic viscosity coefficient
	183	OPCON(3)	Maximum change in velocity. If the change is greater than OPCON(3), the artificial viscosity coefficient is set to 0.

Equation of State Data

M = 25(N - 1) where N is the material number (1 thru 4).

EQSTC(M+1) thru EQSTC(M+10) are constants for Tillotson's equation of state. EQSTC(M+11) thru EQSTC(M+25) are constants that are required for any form of an equation of state.

Column 1	Columns 4-6	Variable	Description
	431+M	EQSTC(M+1)	ρ_0 (g/cc)
	432+M	EQSTC(M+2)	a
	433+M	EQSTC(M+3)	I_0 (jerk/g)
	434+M	EQSTC(M+4)	b
	435+M	EQSTC(M+5)	A (jerk/cc), bulk modulus
	436+M	EQSTC(M+6)	I_s (jerk/g)
	437+M	EQSTC(M+7)	I_s' (jerk/g)
	438+M	EQSTC(M+8)	α
	439+M	EQSTC(M+9)	β
	440+M	EQSTC(M+10)	B (jerk/g)
	441+M	EQSTC(M+11)	Not used
	442+M	EQSTC(M+12)	Not used
	443+M	EQSTC(M+13)	Not used

Column 1	Columns 4-6	Variable	Description
	444+M	EQSTC(M+14)	Not used
	445+M	EQSTC(M+15)	$10^{-5}*\rho_0$
	446*M	EQSTC(M+16)	$10^{-6}*\rho_0$
	447+M	EQSTC(M+17)	IMELT (jerk/g)
	448+M	EQSTC(M+18)	Y_0 (jerk/g), yield strength in shear
	449+M	EQSTC(M+19)	α in $Y = (Y_0 + \alpha P)(1 - I/IMELT)$
	450+M	EQSTC(M+20)	μ, shear modulus
	451+M	EQSTC(M+21)	ρ/ρ_0 failure criterion
	452+M	EQSTC(M+22)	Maximum pressure in Y function above
	453+M	EQSTC(M+23)	Not used
	454+M	EQSTC(M+24)	Not used
	455+M	EQSTC(M+25)	Specific heat (jerk/g/kev)

VI. SUMMARY AND CONCLUSIONS

Several test problems have been completed to compare the numerical results of an isothermal expansion problem and an impact problem.

For the impact problem, a plane strain (x-y) impact (run with 2DSOIL) was compared to a plane strain (x-y) impact (run with 3DSOIL) with several planes in the z-direction. These results between two-dimensional and three-dimensional numerical techniques proved to be identical thereby giving credibility to the 2DSOIL and 3DSOIL codes.

A circular isothermal expansion in plane strain (run with 2DSOIL) was compared with an equivalent circular isothermal expansion in plane strain (run with 3DSOIL) with several planes in the z-direction. The agreement was identical between the two codes.

Preliminary exploration of incorporating an elastic-plastic strength model in the operator splitting mode indicates that it is feasible. Additional calculations will be required to confirm the results.

The packaging concept (sub-dividing the computational grid into N problems and communicating the necessary information across problem boundaries) may be necessary to enable one to compute large three-dimensional problems. Another possible solution would be to pack several words into a single word. This concept can double the size of the computational cells available for any given problem.

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